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# DATA ANALYSIS OF IBSS AND CIRRIS-1A DATA COLLECTED DURING STS-39

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**Final Report**

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Performed data analysis on the IBSS (Infrared Background Signature Survey) and CIRRIS-1A (Cryogenic Infrared Radiance Instrumentation for Shuttle) data collected during the space shuttle mission STS-39 in the spring of 1991. Analysis of these data included filter waveband studies, construction of two-dimensional imagery from pushbroom scans, Fourier Transform analysis Wavelet Transform analysis, and other statistical estimations to examine the spatial structure content of the radiometric data.

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# Letter Final Report

Dr. John O. Wise
Phillips Laboratory
29 Randolph Road
Hanscom AFB, MA 01731-3010

Dear Dr. Wise:

This letter final report is respectfully submitted to satisfy the requirements of contract F19628-93-C-0055. The contract was active during the period May 1993 to March 1997 and was funded for a total of $1,550,566. As a result of funding limitations, the government descoped the contract by $1.3 million in March 1997, revised the contract completion date, and authorized a final letter report.

Early in this contract we performed data analysis on the IBSS (Infrared Background Signature Survey) and CIRRIS-1A (Cryogenic Infrared Radiance Instrumentation for Shuttle) data collected during the space shuttle mission STS-39 in the spring of 1991. Analysis of these data included filter waveband studies, construction of two-dimensional imagery from pushbroom scans, Fourier Transform analysis, Wavelet Transform analysis, and other statistical estimations to examine the spatial structure content of the radiometric data.

Conclusions drawn from the IBSS 4.3μm background structure data required taking into consideration the filter spectral response in order to ensure the proper application to the development of structure models or future sensors. Estimates of the MODTRAN radiance integrated over the remeasured 4.3μm IBSS filter transmission curves indicated that the narrow filter (5E) had radiance contributions from the blue side (below 4.2μm) of 10-17% and contributions from the red side (above 4.35μm) of 3-5%. Also, the wider filter (2D) had substantial integrated radiance from both the blue and red edges near 4.3μm. A comparison of the Earthscan radiance measurements with MODTRAN estimates showed agreement for the wider (2D) filter and a discrepancy of approximately 50% for the more narrow (5E) filter.

We constructed representative samples of MWIR strip images of BTH and Earth limb scenes. By analyzing the BTH scenes with a conventional PSD and Morlet Wavelet transform, we established the existence of significant non-stationary spatial structure on all scales down to ~1 km; the overall rms variations about the mean were approximately $5 \times 10^{-7}$ Watts/cm$^2$-str (or ~15% of the mean).

Statistically significant spatial structure was also detected with both the wide and narrow IBSS 4.3μm filters in the Earth's limb with rms variations of approximately $3 \times 10^{-8}$ Watts/cm$^2$-str (~2% rms variations about the mean). This structure had a quasi-monochromatic appearance which was further

quantified in the two-dimensional PSD analysis of these scenes. The characteristic angles (~20°) and vertical wavelengths (~16 km) of these features were highly suggestive of gravity waves.

Other activities during the earlier period of this contract included experiment and spectral filter design for the SPAS III Program (Shuttle Palette Satellite). Our experience drawn from the spectral analyses performed in the IBSS and CIRRIS 1A data analysis activities was very valuable for this task. We performed simulations using output from the atmospheric codes (MODTRAN and SHARC) with models of the proposed spectral filters. From the results of these simulations, we could evaluate the performance of the candidate filters and modify the passbands as required. The objective of the set of filters was to experimentally determine the structure dependence on wavelength by varying the red side of the 2.7 and 4.3 micron regions while holding the blue side close to constant.

The major focus of the work effort on this contract was the SPAS III data analysis, for which Visidyne designed and built a software package we called SPASware. This software was an interactive data analysis tool which incorporated many of the analysis algorithms that were written as part of the IBSS/CIRRIS-1A activities as well as some new algorithms designed specifically for SPAS III. Some of the algorithms used for previous data analysis programs had to be modified for specific use on SPAS-like data. The SPAS sensor was very different from those of either IBSS or CIRRIS in that it was a staring focal plane array (256 × 256) as opposed to the detector-array sensors on IBSS and CIRRIS that had to be used in a pushbroom scanning fashion in order to build up a data "image".

SPASware was constructed with a very user-friendly GUI and its focus was geared toward in-depth analysis of a very manageable, limited dataset. We quickly saw the need for a different type of analysis tool; one that could handle large volumes of data and operate in a semi, if not, fully automated manner. We started with the algorithms in SPASware, improved on and added to them based on the changing needs of the backgrounds community and the SBIRS office, and developed the Automated Software Analyzer and Processor (ASAP).

The ASAP software, as its name suggests, was designed to operate in an automated manner, and it has proven to be extremely robust, efficient, and reliable in its performance. It was engineered to be highly modularized for maximum flexibility and to minimize maintenance requirements. ASAP is extremely fault-tolerant in that it includes a very effective error handling and logging mechanism which allows automatic processing to continue even upon failure of an individual image or analysis routine. This feature is essential to the success of a high-volume data processing assignment, as one could not permit prolonged interruption of program execution, nor would one be able to debug problems without an error logging system.

Most of the ASAP algorithms were programmed in IDL (Interactive Data Language) which is a commercially available programming language for use on VMS, UNIX, or PC systems. The Visidyne software was developed on a UNIX system. ASAP's output data products are written as a variable length byte stream. There is a short header (variable length) at the beginning of each data product file which describes the contents and structure of that file. The data output format is fully documented, and is accompanied by readers written in both IDL and C languages.

Examples of the ASAP data products are: minimum, maximum, mean, and median radiances, standard deviation, skewness, and kurtosis of original, gradient, and sigma images; $N^{th}$ percentile radiance values of gradient images; spectral correlation coefficients and slopes; power spectral density (PSD) slopes, and correlation lengths. ASAP also performs a significant amount of geometric computation to aid in the statistical analysis. For example, ASAP computes the angle with which the

camera axes are oriented with respect to the Earth's horizon so that the individual images can be rotated to be aligned with that horizon prior to analysis. In addition, many of the analyses require two images to be co-registered on a pixel by pixel basis; ASAP performs the two necessary forms of co-registration, i.e., below-the-horizon (BTH), requiring reprojection of both images onto a common latitude/longitude grid, and above-the-horizon (ATH) requiring rotation and translation of one image (in camera space) with respect to the other.

The ASAP software also includes a module that constructs mosaic scenes by "stitching" together continuous, overlapping sub-images. This is accomplished using the pointing information available in the data headers. The projection that we have implemented in our LMS ASAP software puts the mosaic into the tangent plane of a sensor located at an arbitrary location in space, viewing the scene (in a single exposure) with a camera of arbitrary angular resolution and field of regard. We chose this type of projection for several reasons, the most important of which is that out of all possible projections, it most accurately mimics a scene which could have been collected by a sensor with a very large field of regard. In our processing of the large mosaic scenes, the algorithm places the "LMS sensor" at approximately 435 km altitude and at the location of the collecting sensor at approximately the center of the satellite track during the LMS data collection event. We set the angular resolution of the LMS to be approximately 200 μrad.

The LMS ASAP process consists of four steps: defining the axes of the tangent plane coordinate system, transforming the "tie points" of each of the sub-images from the original coordinate system to the new coordinate system, reprojecting the sub-images, and approximately averaging the regions of overlap between adjacent sub-images in the mosaic. The software has proven to work extremely well.

Other activities during this contract have included documentation of both SPASware and ASAP, their algorithms, outputs, and formats. We wrote and presented several papers to the IRIS TBD meetings, and IEEE Aerospace meetings. We also participated in many Background Working Group, Data Review, and Calibration Meetings, and provided support to the SBIRS PEP and other higher level meetings in the form of briefing materials.

Sincerely,

Cynthia Beeler

cc: Alfred Parino
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